主論文

糖分解の研究

速水醇一

主論文第1部

Studies on the Chemical Decomposition of Simple Sugars XI. Acetol Formation from ^{14}C-Labeled Pentoses.

By Jun'ichi HAYAMI

(Organic)

Studies on the Chemical Decomposition of Simple Sugars XI. Acetol Formation from ^{14}C-Labeled Pentoses*)

by Jun'ichi HAYAMI

In the preceding report[1], formation of acetol from position labeled hexoses was examined, and an examination revealed the origins of every carbon atoms of acetol produced. The terminal carbons of hexoses were found to be converted into methyl carbon of acetol.

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*) Presented before the 13th Annual Meeting of the Chemical Society of Japan, Tokyo (1960).

1) R. Goto, J. Hayami, K. Kudo, and S. Otani, This Bulletin, 34, (1961).

Moreover, some characteristic properties of the reaction were suggested that on one of the steps of the reaction, a cleavage in the carbon chain of an intermediate appeared between the C-3 and the C-4 of the original hexose, and that no skeletal rearrangement in the C_3-group was involved before and after the splitting of the chain.

In a series of papers of the same title, two different mechanisms of acetol formation were proposed[1)], the one — Nodzu's mechanism[2a)] — assumed an intermediate formation of acetylformoin from a hexose, and the other — Goto's mechanism — assumed an intramolecular oxidation-reduction of 3-deoxyhexosone. Goto's challenge for Nodzu's mechanism[2b)], had its starting point in the need of a general interpretation for the acetol formation from pentose and hexose, he infered from Nodzu's mechanism that if it was applied to a pentose, it could not lead to formation of acetol. However, a pentose gives acetol as well as a hexose does. Therefore, for establishment of a general mechanism of acetol formation, it is important to decide whether there is a common mode of reaction between the mode of acetol formation from pentose and that from hexose.

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2)a) R. Nodzu, et al., Mem. Coll. Sci. Kyoto Imp. Univ., A20, 197 (1937).

b) R. Goto, J. Chem. Soc. Japan (NIPPON KAGAKUKAISI), 64, 999, 1054 (1943).

In the present work, D-xylose-1-^{14}C and D-arabinose-5-^{14}C were synthesized and these were decomposed in concentrated buffer solution of potassium acid phosphate and acetol was isolated. The relative distribution of a label was, then, determined.

Experimental

Labeled Sugars and Assay Method.

a) D-xylose-1-^{14}C.— D-xylose-1-^{14}C was synthesized from D-glucose-1-^{14}C by Sowden's method[3] with an improvement in the reduction procedure*), that is, instead of the catalytic hydrogenation of 1,2-O-isopropylidene-D-xylo-dialdopento-furanose (I)**), reduction with lithium aluminum hydride was adopted as was case with the synthesis of 3-O-methyl-D-xylose by Corbett[4].

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*) Isbell et al. also proposed an elegant method of reduction with $LiBH_4$ in tetrahydrofuran. (H. S. Isbell, et al., J. Research N.B.S., 64A, 359 (1960)).

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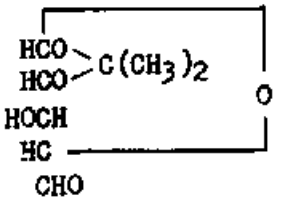

(I) or its dimeric form.

3) J. C. Sowden, J. Amer. Chem. Soc., 73, 5496 (1951).

4) W. M. Corbett, G. N. Richards, and R. L. Whistler, J. Chem. Soc., 11 (1957).

(I) was prepared from 2.5 g. of D-glucose-1-^{14}C according to Sowden's method. Ethereal solution (70 ml.) of (I) was placed in a two-necked flask equipped with a dropping funnel and a reflux condenser. Lithium aluminum hydride (0.75 g.) in ether (75 ml.) was added dropwise in 30 minutes; the mixture was refluxed for 30 minutes. Excess of lithium aluminum hydride was decomposed with ethyl acetate (2.5 ml.) and water (45 ml.); ether on the upper layer was removed by air current. Residual aqueous solution was neutralized with dil. H_2SO_4 and filtered. The filtrate was concentrated under reduced pressure. The residual light sirup was dissolved in 60 ml. of 0.1 N H_2SO_4 and heated in a boiling water bath for an hour. After cooling, the hydrolysate was passed through an ion-exchange resin (10 ml. of Amberlite IR-120 and 25 ml. of Amberlite IR-45). The effluent and the washing were combined and concentrated under reduced pressure. D-xylose-1-^{14}C often crystallized on concentration. However, if neccesary, the solution was lyophilized after concentration to an appropriate volume, and the residue was crystallized from methanol-isopropanol in the usual way[5]. Yield; 1.5 g. or 72 % (in typical run).

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5) cf. H. S. Isbell, et al., J. Research N. B. S., 48, 163 (1952).

b) D-Arabinose-5-^{14}C.—— D-Arabinose-5-^{14}C was synthesized by Ruff degradation according to Isbell[6].

c) Radioassay.—— Every sample was converted into $BaCO_3$ by Van Slyke-Folch wet combustion. $BaCO_3$ was collected on filter paper, and counted in an infinite thickness in a 2π-gas flow counter*). Only CHI_3 was counted in a medium thickness and corrected for an infinite thickness by paralleled counting of the parent sugar of about an equal thickness. Probable errors of the counting were all within 5 %.

Decomposition of Labeled Pentose.—— Ten grams of arabinose or xylose was dissolved into 200 ml. of concentrated solution of potassium acid phosphate (40 %, pH 6.7); the mixture was heated and distilled in the way described earlier[1,7].

Degradation was carried out in the same way as reported earlier[1], but degradation of the acetic acid was not undertaken. Radioactivity of the carbonyl carbon of acetol was determined indirectly from the total activity of acetol less the activities of methyl and carbinol carbon. These data are summarized in Table I.

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6) H. S. Isbell, N. B. Holt, and H. L. Frush, ibid., 57, 95 (1956).

*) A product of Metro Electronic Institute, Kyoto.

7) R. Nodzu, This Bulletin, 10, 122 (1935).

Table I. Radioassay Data for ^{14}C-Labeled Pentoses.

Samples		carbon atom(s)	radioactivity (μ c/mole)
Radioacetol from D-xylose-1-^{14}C			
xylose-1-^{14}C			19.6
acetol	acetol semicarbazone	all	9.7
	iodoform	CH_3	9.5
	indirectly determined	CO	-*)
	formaldehyde dimedone	CH_2OH	almost 0
Radioacetol from D-arabinose-5-^{14}C			
arabinose-5-^{14}C			257
acetol	acetol semicarbazone	all	136
	iodoform	CH_3	125
	indirectly determined	CO	-*)
	formaldehyde dimedone	CH_2OH	14

*) Substantially free from radioactivity.

Results and Discussion

The results from radioassay may be expressed in the following way.

I) In the case of D-xylose-1-^{14}C, radioacetol of about a half specific radioactivity of the parent xylose was obtained.

On the degradation, the methyl carbon of acetol was converted into iodoform which contains substantially all the activity of the acetol. The carbinol carbon of acetol was converted into formaldehyde by periodate oxidation and was captured as formaldehyde dimedone which was found almost free from activity. In consequence, xylose-1-^{14}C was proved to produce acetol-3-^{14}C (methyl-^{14}C).

II) D-arabinose-5-^{14}C similarly yielded radioacetol of about a half specific activity of the original arabinose.

The degradation gave iodoform which contains almost all the radioactivity of parent acetol, however a slight degree of activity was observed for formaldehyde which was derived from carbinol carbon of acetol.

Therefore, it may be concluded that arabinose-5-^{14}C produces acetol-3-^{14}C.

The above results are in accord with the expectation from a tracer experiment of hexoses, that is, the terminal carbon of a pentose —C-1 and C-5— are converted into methyl carbon of acetol.

These facts suggest that a common mechanism operates in the formation of acetol from simple sugars.

From Table I, a similar behaviour of D-arabinose-5-^{14}C and D-xylose-1-^{14}C in the formation of acetol is perceived. These facts constitute the characteristics of the acetol formation from a pentose.

Neglecting the effect of a difference in configuration between arabinose and xylose, also neglecting the slight randomization of a lable, the contribution ratio of the upper C_3 and the lower C_3 of a pentose may be postulated as about 1 : 1[8]. Almost an equal contribution of upper and lower C_3 part of a pentose for formation of acetol, suggests participation of an intermediate of a good symmetrical structure. This means destruction of the configurational difference between arabinose and xylose to yield an intermediate of common or analogous nature through some transformation reaction of a pentose*).

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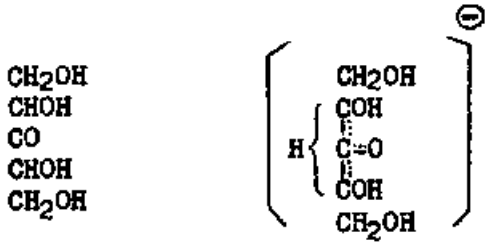
*) In addition, there is no essential difference between the acetol formation and a configuration of a monosaccharide. Also refer to R. Goto (loc. cit.)

8) H. F. Bauer, and C. Teed, Can. J. Chem., 33, 1824 (1955). Also refer to M. Gibbs, J. Amer. Chem. Soc., 72, 3964 (1950).

In such a reaction an isomerization of a sugar plays an important role on the essential pathway of the reaction, an effect of symmetrical natures of an intermediate may be often visualized[9].

An examination of the mechanism of acetol formation, which will be discussed in detail in a succeeding paper[10], suggests the above intermediate to be 3-ketopentose (II) or its enediolate*,[11,12] (III), in which, the configurational difference between arabinose and xylose is destroyed.



(II) (III)

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*) Or their equivalent compounds.

9) J. C. Sowden, M. G. Blair, and D. J. Kuenne, J. Amer. Chem. Soc., 79, 6450 (1957).

10) J. Hayami, This Bulletin, 34, (1961).

11) R. L. Whistler, and J. N. BeMiller, Advances in Carbohydrate Chem., Vol. 13, 289 (1957).

12) J. C. Sowden, ibid., Vol. 12, 36 (1957).

J. C. Speck, Jr., ibid., Vol. 13, 63 (1958).

Acknowledgements

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Chemistry Institute
Faculty of Science
Kyoto University
Sakyo-ku Kyoto

主論文第2部

Studies on the Chemical Decomposition of Simple Sugars XII.

Mechanism of the Acetol Formation

By Jun'ichi HAYAMI

(Organic)

Studies on the Chemical Decomposition of Simple Sugars XII. Mechanism of the Acetol Formation*)

By Jun'ichi HAYAMI

Decomposition of partially ^{14}C-labeled hexoses and of pentoses, which was reported in preceding papers[1,2] revealed the origin of every carbon atom of a resulting acetol, and the terminal carbons of a hexose and of a pentose (C-1 and C-6 of a hexose, C-1 and C-5 of a pentose) were found to be converted into the methyl carbon of acetol.

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*) Presented before the 13th Annual Meeting of the Chemical Society of Japan, Tokyo (1960).

Part XI., the preceding paper.

1) R. Goto, J. Hayami, K. Kudo, and S. Otani, This Bulletin, 34, (1961).

2) J. Hayami, ibid., 34, (1961).

The next step is to elucidate the mechanism through which the methyl or acetyl group of acetol is formed.

As was already pointed out[2),3)], triose can not be an essential intermediate in the formation of acetol from a monosaccharide. Accordingly, a direct transformation of a C_5 and of a C_6 compound is regarded to take place. Generally speaking, except for hydrogenolysis and catalytic hydrogenation, examples of a direct reduction of an aldehydic or a primary carbinol group into a methyl group are scarce, especially in an aqueous reaction medium. In the present instance of acetol formation, aldose may be transformed into a ketose, and the C-1 (and C-5 or C-6) of a ketose may be converted into methyl through one of the following three possible mechanisms.

a) $CH_2OH(CHOH) \longrightarrow CH_2{=}C(OH)(CHOH) \longrightarrow CH_3CO(CHOH)$

b) $CH_2OH\,CO(CHOH) \xrightarrow{RCHO} CH_3CO(CHOH) + (RCOOH)$

c) $CH_2OR\,CHOH\,CO \longrightarrow CH_2{=}C(OH)CO + OR^{\ominus}H^{\oplus} \longrightarrow CH_3CO\,CO$ (R: alkyl or hydrogen)

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3) R. Goto, J. Chem. Soc. Japan (NIPPON KAGAKUKAISI), 64, 999, 1054, 1183 (1943) ; Mem. Coll. Sci. Kyoto Imp. Univ., A 20, 197 (1937).

They are:

a) Simple dehydration of vic-diol, which is similar to the thermal decomposition of glycerol[4].

b) Mutual oxidation and reduction between α-ketol and aldehyde, a reaction which is analogous to the levulinic acid formation from 5-hydroxylevulinic aldehyde[5].

c) β-hydroxy-carbonyl elimination from 3-ketose or its equivalent compound, a reaction which prevails in the reaction of carbohydrates[6,7].

Among these reactions, the possibility of a) can be ruled out, because sugar alcohol such as mannitol yields no acetol by the action of phosphate under decomposition condition[8].

As for b), though this mechanism has been believed to operate in the formation of levulinic acid from hydroxymethylfurfural, there are challenges to this view[9], and

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4) J. U. Nef, Ann., 335, 247 (1904).

5) F. H. Newth, Advances in Carbohydrate Chem., Vol. 6, 83 (1951), and references cited therein.

6) J. C. Sowden, ibid., Vol. 12, 36 (1957).

7) R. L. Whistler, and J. N. BeMiller, ibid., Vol. 13, 289 (1958).

8) R. Goto, unpublished work.

9) A. P. Dunlop, and F. N. Peters, "Furans", Reinhold, New York, (1953) p. 648.

in some cases, even an intermediate formation of 5-hydroxylevulinic aldehyde is accepted with doubt[10]. In the Teunissen's mechanism[11], 5-hydroxylevulinic aldehyde is to be converted into levulinic acid through (an intramolecular) acetal formation. This mechanism requires a specific arrangement of a hydroxyl group and an aldehydic group and, in an aqueous medium, an example of acetal formation between separated alcohols and aldehydes is yet unknown. When the above mentioned acetal formation is to be regarded to proceed if any, it can be inhibited through O-alkylation at C-1 and/or C-6 of a hexose (C-1 and/or C-5 of a pentose), because no acetal can be produced by action of ether upon an aldehyde. Therefore, acetol formation from 1-O-alkylated sugars must be retarded.

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10) F. Leger, and H. Hibbert, Can. J. Research, 16B, 68 (1938).

11) H. P. Teunissen, Rec. trav. chim., 50, 1 (1930).
R. Pummerer, and W. Gump, Ber., 56, 999 (1923).
R. Pummerer, O. Guyot, and L. Birkofer, ibid., 68, 480 (1935).

As for c), on the other hand, the introduction of an O-alkyl group on C-1 (or C-5, C-6) may facilitate the β-hydroxy-carbonyl elimination from 3-ketose to convert the C-1 into methyl group, thus the formation of acetol from the sugar may be accelerated.

In the present work, 1-O-methyl-D-fructose (I), 3-O-methyl-D-glucose (II), and 6-O-methyl-D-glucose (III) were decomposed to decide which of these two cases actually occurs, and combining the results with those of tracer experiments reported earlier, a general mechanism of acetol formation was made clear.

Experimental

Methylated Sugars.— 1-O-Methyl-D-fructose[12] was synthesized from sucrose through di-O-isopropylidene fructose, and 3-O-methyl-D-glucose[12] was synthesized from glucose through di-O-isopropylidene-D-glucose in the usual way. 6-O-methyl-D-glucose was synthesized through 1,2-O-isopropylidene-6-O-tosyl-D-glucose and 1,2-O-isopropylidene-5,6-epoxy-D-glucose according to the combination of Reist's method[13] with Ohle's method[14].

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12) W. L. Glen, J. Chem. Soc., 2568 (1951).

13) E. J. Reist, et al., J. Org. Chem., 23, 1753 (1956).

14) H. Ohle, and L. Vargha, Ber., 62, 2435 (1929).

Decomposition of Methylated Sugars.— A solution of 5.4 g. of 1-O-methyl-D-fructose or 6-O-methyl-D-glucose in 200 ml. of concentrated potassium acid phosphate buffer (40 %, pH 6.7), was heated and distilled in the usual way which was described earlier in a paper[1] (Part X of this series). In the case of 3-O-methyl-D-glucose, 10.8 g. of the sugar was decomposed in the same way. In the reference experiment, each 5 g. or 10 g. of parent sugar was decomposed.

Estimation of acetol in a distillate[15].— To 10 ml. of the distillate were added 10 ml. of N/10 KI-I_2 solution and 10 ml. of 10 % KOH solution. After 30 minutes, the mixture was acidified with 8 ml. of 15 % hydrochloric acid, and liberated iodine was titrated with N/10 $Na_2S_2O_3$ standard solution. One ml. of N/10 KI-I_2 solution corresponds to 0.73 mg. of acetol. The amount of acetol was plotted against time, thus distillation curves were given for each sugar and derivative respectively (Fig. 1~3).

Every distillate was collected, and acetol in the distillate was treated with 5-fold equivalents of semicarbazide hydrochloride and sodium acetate. The mixture was heated over boiling water bath for 30 minutes, cooled and concentrated under reduced pressure. Acetol semicarbazone was separated and repeatedly recrystallized from hot water to give colorless needles. m.p. and mixed m.p. 199~200°C.

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15) R. Nodzu, This Bulletin, 10, 122 (1935).

Table

Acetol formation from partially O-methylated hexoses.

samples		distillate (ml)	acetol*) (mg)	acetol semicarbazone (mg)
		3-O-methyl-D-glucose		
3-O-methyl-D-glucose	10.8 g.	2400	79.3	0
glucose	10.0 g.	2400	251.6	70
		1-O-methyl-D-fructose		
1-O-methyl-D-fructose	5.4 g.	3000	269.8	83
fructose	5.0 g.	3000	218.2	65
		6-O-methyl-D-glucose		
6-O-methyl-D-glucose	5.4 g.	3000	322.6 (288.9)**)	100
glucose	5.0 g.	3000	223.7	60

*) Calculated from the titration of iodine consuming substances. (assuming only acetol was present).

**) Corrected value from the peak height of UV-absorption spectrum.

Results and Discussion

The results which are shown in the above table and figures can be expressed as follows.

i) In the case of 3-O-methyl-D-glucose (II), the formation of iodine consuming substances were depressed in a marked degree. Acetol semicarbazone could not be isolated, and the UV-absorption spectrum of the distillate did not show the characteristics[16] of acetol. Thus, the introduction of 3-O-methyl group was shown to hinder the formation of acetol from glucose.

ii) On the other hand, remarkably rapid formation of acetol from 1-O-methyl-D-fructose (I) was observed, the rate of formation was about twice that from the parent fructose. Acetol semicarbazone was actually isolated from the decomposition distillate of 1-O-methyl-D-fructose as well as from that of D-fructose.

iii) 6-O-methyl-D-glucose (III) also showed enhanced rate of acetol formation, and the amount of acetol was even greater than that of glucose. The amount of acetol estimated by iodometric titration was corrected by the peak height of UV-absorption spectrum and was shown in Fig. 3 (dotted line). These facts might mean that the introduction of 6-O-methyl group would raise the amount of acetol formation but not the rate of formation.

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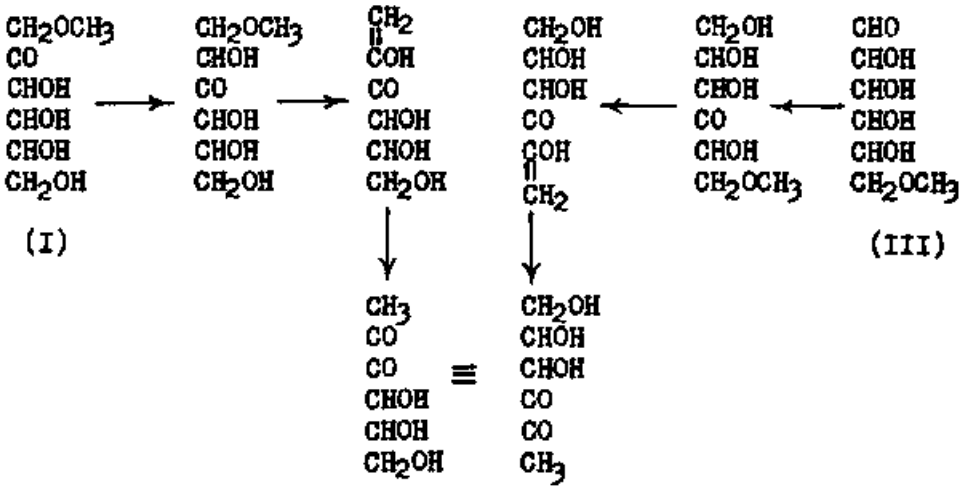
16) R. Nodzu, and R. Goto, This Bulletin, 11, 381 (1936).

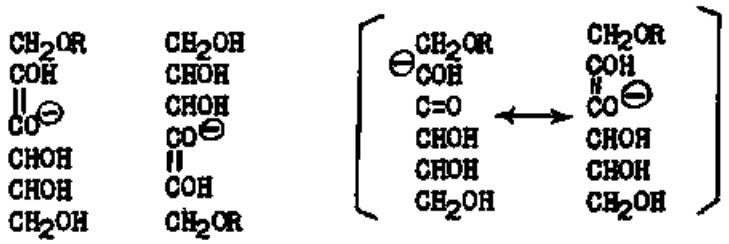
It is well known[6,7] that O-alkylation of the hydroxyl group located at the β-position to the carbonyl group always facilitates an elimination of alkoxyl anion more (compared with that of hydroxyl anion from parent compound).

In the present instance, the formation of acetol was accelerated by introduction of 1-O-methyl (and 6-O-methyl) group into hexose. These facts mean that β-hydroxy-carbonyl elimination from 3- (and/or 4-) ketohexose is operating on an essential pathway of this reaction, and that oxidation-reduction mechanism (the pathway b) cited above) do not play an important role.

These processes may be written as follows:



3- or 4- ketohexose in the above scheme may actually be a hexose-2,3- or 3,4-enediol. According to Isbell[17] (IVa,b) and to Whistler[7] (IVc), a direct intermediate from which alkoxyl anion is eliminated may be an enediolate anion.



(IVa) (IVb) (IVc)

These enediol or enediolate are quite probable intermediates in the transformation of sugars[18], in fact Sowden[19] offered a solid experimental evidence of the existence and of the important role of the hexose-3,4-enediols in the isomerization of hexose.

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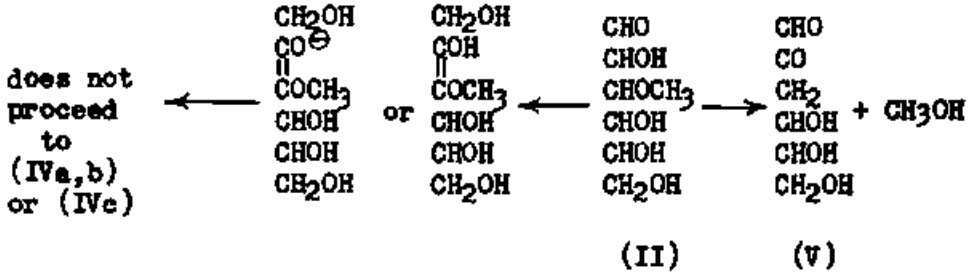
17) H. S. Isbell, J. Research N.B.S., 32, 45 (1944); and also refer to the excellent reviews by Sowden (loc cit).

18) J. C. Speck, Jr., Advances in Carbohydrate Chem., Vol. 13, 63 (1958).

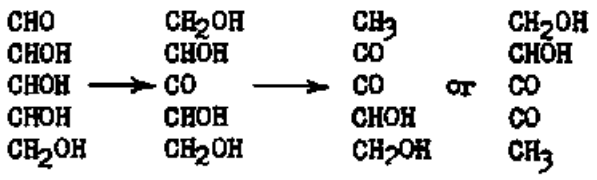
19) J. C. Sowden, and R. R. Thompson, J. Amer. Chem. Soc., 80, 1435 (1958).

With above illustrations, the behaviour of 3-O-methyl-D-glucose (II) can be well understood in the following way.

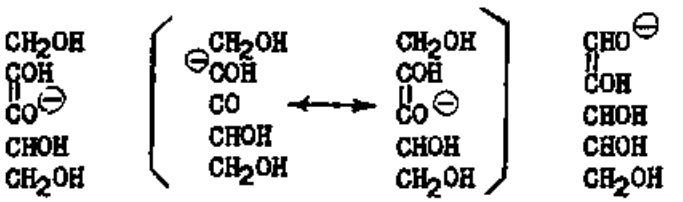


First, under the influence of carbonyl group located at C-1, the elimination of $OR^{\ominus}$ ($OCH_3^{\ominus}$) anion from 3-position (β- to the carbonyl group) is facilitated. Thus, 3-deoxyosone (V) (or its enol form) may be formed, and make it difficult to transform the C-1 into methyl group. Second, 3-O-alkyl group hinders the enol traverse down the carbon chain to form (IVa,b) or (IVc), which is required for formation of acetol.

When the above illustrations are applied to a pentose, β-hydroxy-carbonyl elimination from a 3-ketose will proceed as follows:



The actual intermediates from which hydroxyl anion is eliminated may be an enediolate anion (VIIa) or (VIIb). These enediolate anions would be derived either directly from (VI) or from (VIII) by prototropy.

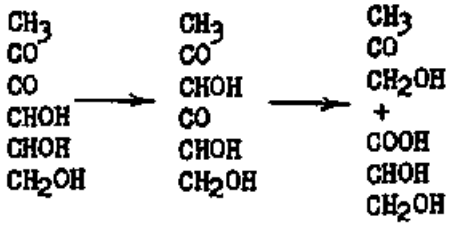


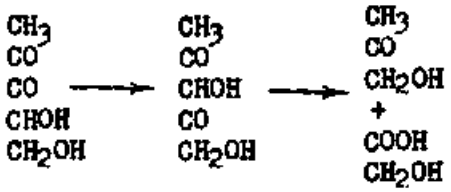
(VIIa) (VIIb) (VIII)

Examination of these formulae of the intermediate shows that β-hydroxy-carbonyl elimination may take place either at C-1 or at C-5 with equal chance. Or strictly speaking, contribution of the lower C_3 part of the pentose may be greater than that of the hexose. In other words, the intermediate for formation of acetol from a pentose might have a good degree of symmetry. This was proved to be the case as was described in Part XI of this series of papers[2].

From the above discussion, it should be clearly evident that β-hydroxy-carbonyl elimination from 3-ketose (and/or from 4-ketose in the case of hexose) takes place as an essential part of the general mechanism of the acetol formation.

Fate of the α-diketones, formed by β-hydroxy-carbonyl elimination, is supposed as follows:





i) In the pH region where formation of acetol is to be observed (pH 3~11), these α-diketones do not rearrange*) by a benzilic acid type of reaction to yield saccharinic acids.

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*) A benzilic acid type of rearrangement proceeds with a rate proportional to concentration of $OH^{\ominus}$ ion.
In addition, in one of the most simple example of the rearrangement, methylglyoxal produces lactic acid (cf. J. C. Sowden, and E. K. Pohlen, J. Amer. Chem. Soc., 80, 242 (1958).) only in alkaline solution that is stronger than N/100 NaOH (about pH 12) (cf. V. Prey, et al., Monatsh., 85, 1186 (1954).).

ii) These α-diketones would be isomerized into β-diketones*) (diacylcarbinols), and then hydrolytically cleft into α-ketol and acid.

iii) Among these processes, no skeletal rearrangement of the C_6 and of the C_5 chain would take place, and this third supposition had its evidence already described in the Part X of this series of the paper[1].

Isomerization of the α-diketone into β-diketone (diacylcarbinol), is one of the general transformations of ketol, and an example by Hesse and Stahl[20] illustrates a quite resembled reaction of the isomerization of pentane-2,3-dione-4-ol to diacetyl carbinol.

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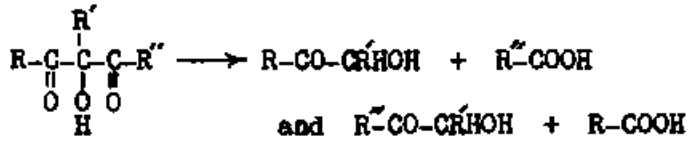
*) Further β-hydroxy-carbonyl elimination from this β-diketone, might result. In the case of hexose, $CH_3COCOCHOHCOCH_3$ (Nodzu's acetylformoin) may result by elimination reaction. As was reported earlier, Nodzu confirmed the formation of acetol and of pyruvic acid by a (hydrolytic) cleavage of this compound.

In a sense, the present work appears to offer a theoretical and experimental evidence for part of Nodzu's mechanism, and the present author will not exclude the possibility that in the case of hexose Nodzu's mechanism operates as a minor pathway of the acetol formation.

20) G. Hesse, and H. Stahl, Ber., 89, 2414 (1956).

Resulting diacylcarbinol is quite reactive and is facile to be cleft hydrolytically according to the following general formula[21,22,23,24].



$$R\text{-}C(=O)\text{-}C(R')(OH)\text{-}C(=O)\text{-}R'' \longrightarrow R\text{-}CO\text{-}CR'HOH + R''COOH$$

and $R''CO\text{-}CR'HOH + R\text{-}COOH$

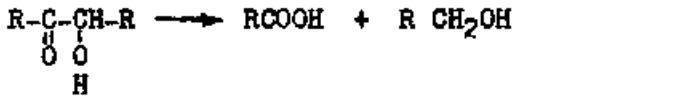
$R' = R'' = Et$, $R = Me$ (House[21])

$R = R' = R'' = Me$ (Juni, and Heym[22])

$R = R'' = Me$, $R' = H$ (Combes[23])

$R = R'' = Ph$, $R' = H$ (Karrer[24])

This hydrolytic cleavage can be taken as an extreme case of an acyloin cleavage[25] which is shown as follows:



$$R\text{-}C(=O)\text{-}CH(OH)\text{-}R \longrightarrow RCOOH + R\,CH_2OH$$

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21) H. O. House, and W. F. Ganon, J. Org. Chem., 23, 879 (1958).

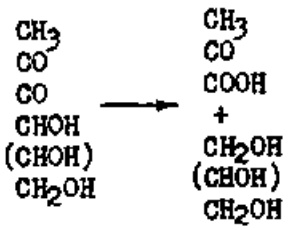
22) E. Juni, and G. A. Heym, Arch. Biochem. Biophys., 67, 410 (1957).

23) A. Combes, Compt. rend., 111, 421 (1890).

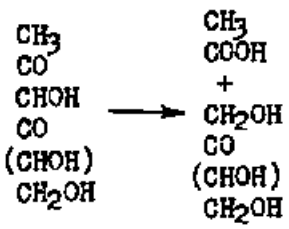
24) P. Karrer, et al., Helv. Chim. Acta, 33, 1711 (1950); 34, 1014, 1498 (1952).

25) D. B. Sharp, and E. L. Miller, J. Amer. Chem. Soc., 74, 5643 (1952).

These hydrolytic cleavage may take part to constitute the side reactions in the following way:



(pyruvic acid formation)



The accompanying formation of pyruvic acid with acetol is already referred to[26]. But the origins and the mode of the formation of the another minor products still remain to be resolved.

As for the role of acid phosphate in the formation of acetol, it is assumedly infered a) acting as an effective buffer solution keeping the pH of the solution nearly constant.

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26) R. Nodzu, et al., Mem. Coll. Sci. Kyoto Imp. Univ., A 20, 197 (1937).

Except these buffer, the pH of the solution decreases remarkably to about 3*). b) acting as a base as well as to act as an acid, thus to promote the transformation of sugars[18] and to promote elimination of $OH^{\ominus}$ anion and of a proton from some intermediates. c) raising the reaction temperature and raising the dielectric constant of the solution to facilitate the ionic processes. These inferences will be examined in detail in future studies.

Essential features of the formation of acetol can be summarized in the following sequences and are expressed in the scheme shown below.

I) Isomerization of monosaccharides to produce 3-ketoses (and/or 4-ketose in the case of hexose) or their equivalent intermediates.

II) β-Hydroxy-carbonyl elimination from the 3-ketose to yield methyl-α-diketones.

III) Hydrolytic cleavage of β-diketone (diacylcarbinol) produced by the isomerization of methyl-α-diketone.

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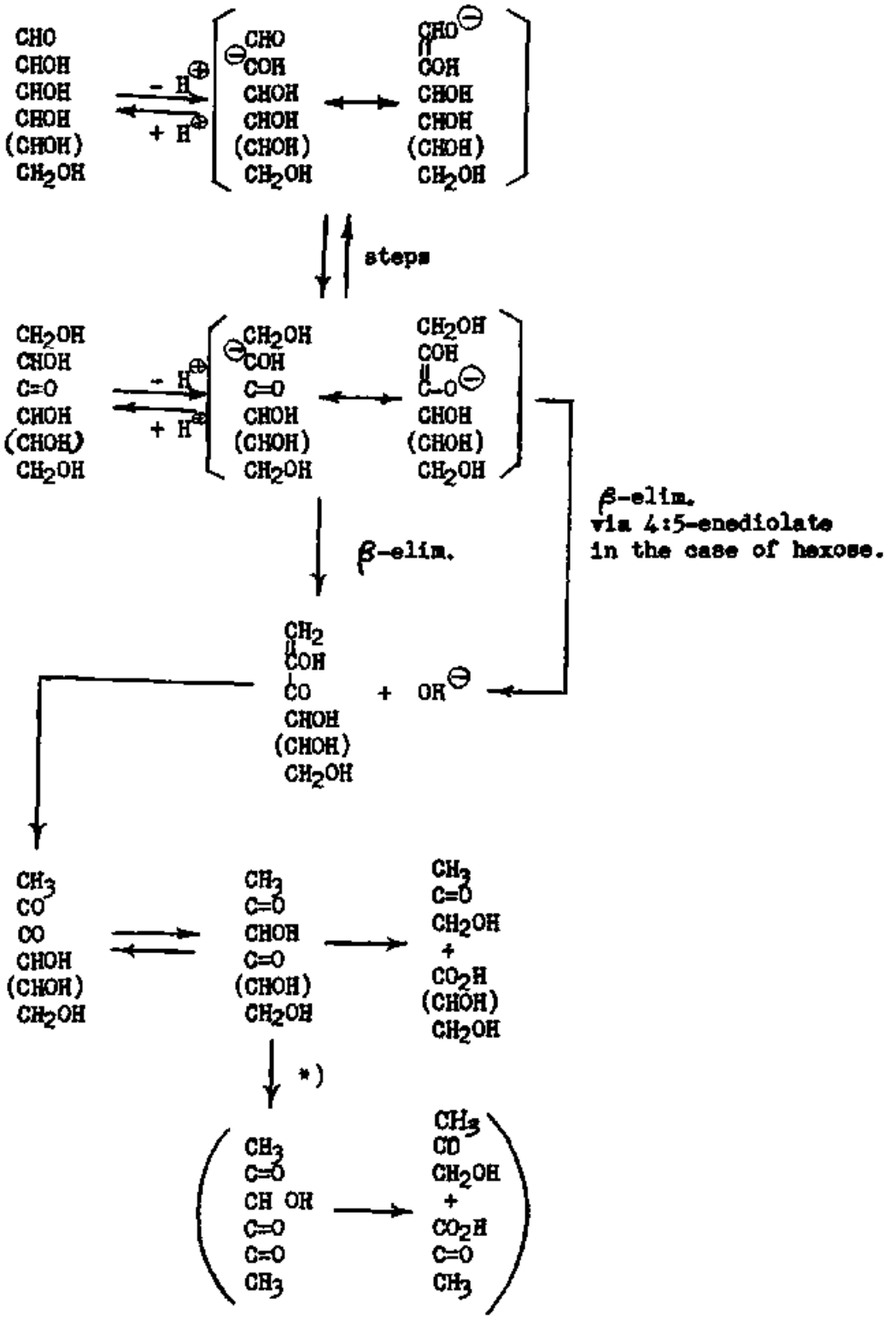
*) Formation of acetol is to be seen at pH 3~11 with an increased yield with the increase in pH. Also refers to R. Montgomery, and L. F. Wiggins, J. Soc. Chem. Ind., 66, 31 (1947); M. L. Wolfrom and W. L. Shilling, J. Amer. Chem. Soc., 73, 3557 (1951).



*) in the case of hexose

The formation of acetol constitutes one example of a new combination of the two basic reactions of carbohydrate chemistry —— the transformation (van Eckenstein reaction) and the benzilic acid type of rearrangement. While no transformation and no rearrangement occur in the furfural formation, saccharinic acid formation requires both the transformation and the rearrangement, and metasaccharinic acid formation requires no transformation but requires rearrangement. In the present case, the transformation is not followed by the rearrangement.

In the present instance, needless to add, much possibility of another pathway which competes with the acetol formation is expected though the nature of such a competing reaction is at all unknown.

Study on the unit reactions involved in the present instances is in progress and will be reported later.

Acknowledgement

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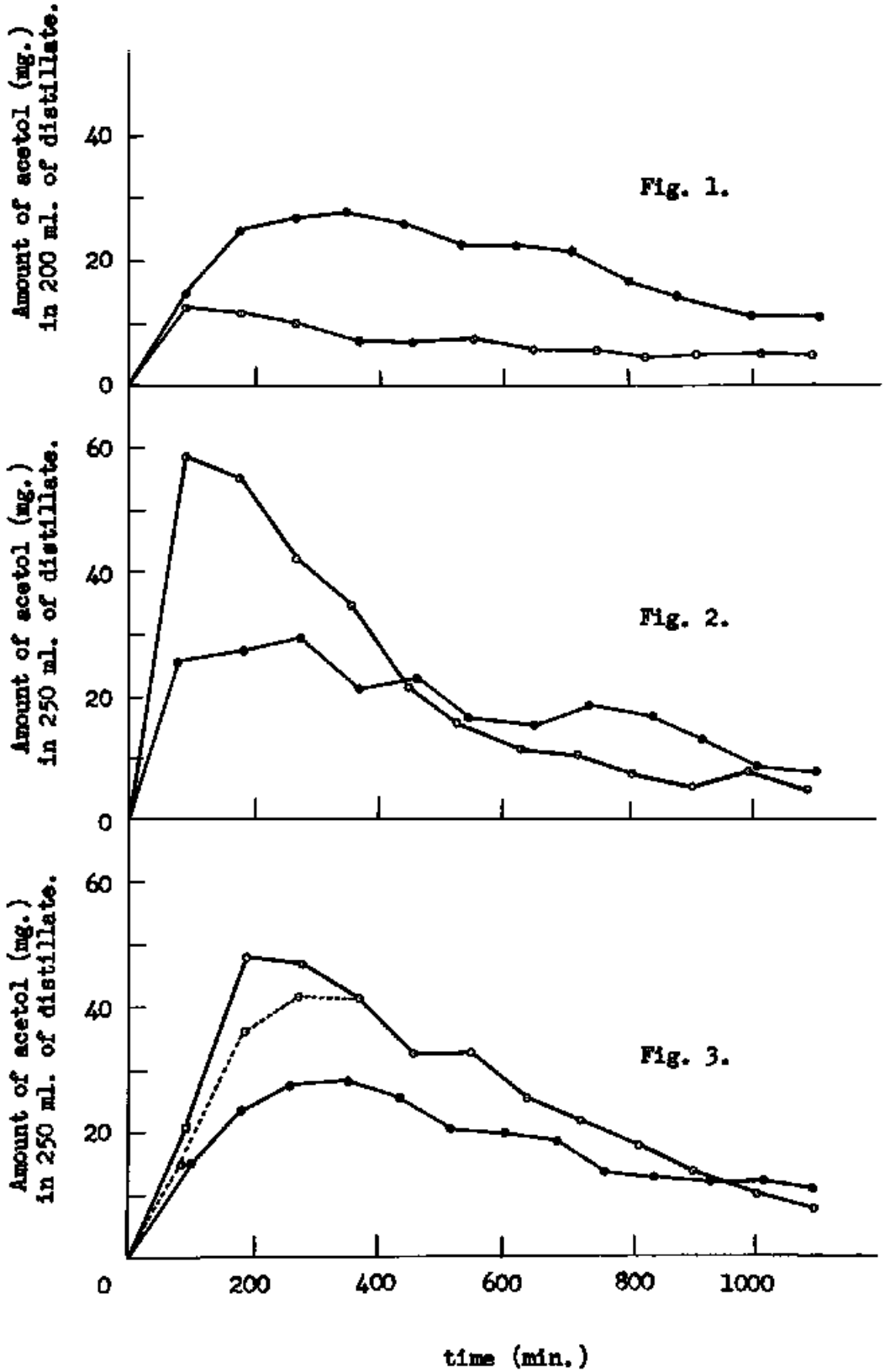
Chemistry Institute
Faculty of Science
Kyoto University
Sakyo-ku, Kyoto

Fig. 1. Acetol formation from 3-O-methyl-D-glucose (○) and from D-glucose (●). The amount of acetol was determined by iodometric titration (iodine-consuming substance was proved not to be acetol in the case of 3-O-methyl-D-glucose).

Fig. 2. Acetol formation from 1-O-methyl-D-fructose (○) and from D-fructose (●). The amount of acetol was determined by iodometric titration.

Fig. 3. Acetol formation from 6-O-methyl-D-glucose (○) and from D-glucose (●). The amount of acetol was determined by iodometric titration and corrected by UV-absorption measurement (dotted line, in the case of 6-O-methyl-D-glucose).

(Figures are on the opposite page.)


Amount of acetol (mg.) in 200 ml. of distillate.
0
20
40
Fig. 1.
Amount of acetol (mg.) in 250 ml. of distillate.
0
20
40
60
Fig. 2.
Amount of acetol (mg.) in 250 ml. of distillate.
0
20
40
60
Fig. 3.
0
200
400
600
800
1000
time (min.)